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Sandia National Laboratories
Waste Isolation Pilot Plant (WIPP)

Disturbed Rock Zone (DRZ) Characterization Test Plan TP 02-04, Rev. 0

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1 ABBREVIATIONS, ACRONYMS, AND INITIALISMS

AE	acoustic emission
AIS	Air Intake Shaft
Cal Lab	SNL Primary Standards Calibration Laboratory
DAS	data acquisition system
DOE	Department of Energy
DOE/CBFO	Department of Energy/Carlsbad Filed Office
DRZ	disturbed-rock zone
EPA	Environmental Protection Agency
ES&H	environmental safety and health
HA	Hazard Analysis
ID	inside diameter
Drill Crew	WTS Mine Drill Crew
kHz	Kilohertz
MB	marker bed
Mine Ops	WTS Mine Operations Department
MOC	Managing and Operating Contractor
NP	(SNL NWMP) Nuclear Waste Management Procedure
NQ	non-QA
NWMP	(SNL) Nuclear Waste Management Program
OD	outside diameter
PA	performance Assessment
PHS	Primary Hazard Screening
PI	SNL/CPG Principal Investigator, or Designee
PZT	Piezoelectric Transducer
QA	quality assurance
QAPD	QA program document
Records Center	SNL/CPG Records Center
SHHCD	Safety and Health Hazards Control Document
SNL	Sandia National Laboratories
SNL/CPG	Sandia National Laboratories/Carlsbad Programs Group
SP	(SNL NWMP) Activity/Project Specific Procedure
Survey Crew	WTS Mine Survey Crew
TP	test plan
US	United States
TRU	Transuranic
U/G Services	WTS Underground Services
WIPP	Waste Isolation Pilot Plant
Work Control	WIPP Work Control Process
WTS	Washington TRU Solutions LLC

2 REVISION HISTORY

This is the original edition of this test plan (TP); no prior versions exist. The purpose and content of any future changes and/or revisions will be documented and appear in this section of revised editions. Changes to this TP, other than those defined as editorial changes per Sandia National Laboratories Nuclear Waste Management Program (SNL NWMP) Quality Assurance (QA) Procedure NP 20-1 (see Subsection 9.4), shall be reviewed and approved by the same organization that performed the original review and approval. All TP revisions will have at least the same distribution as the original document.

3 PURPOSE AND SCOPE

The Waste Isolation Pilot Plant (WIPP) is a United States (US) Department of Energy (DOE) mined, underground repository, certified by the Environmental Protection Agency (EPA), designed for the safe management, storage, and disposal of transuranic (TRU) radioactive waste resulting from the United States defense programs. The wastes are emplaced in panels excavated at a depth of 2,150 ft in the Permian Salado Formation. Following emplacement of waste and the MgO engineered barrier material, the panels will be isolated from the operational mine using an approved closure system. The repository is linked to the surface by four shafts that ultimately will be decommissioned and sealed.

The Salado Formation comprise a thick series of bedded evaporates, dominated by halite, with interbedded sulfate-rich anhydrite and polyhalite layers, and a number of thin clay seams. The repository is excavated in a near-pure halite layer, located immediately above one of the thicker anhydrite layers, known as Marker Bed (MB) 139. Around openings such as drifts, shear stresses will be created that will drive both brittle failure at the grain scale and plastic creep, which may in turn produce further brittle failure. Compared to other crystalline rocks, salt creeps readily in response to stress differences. As a result of these non-elastic processes a disturbed rock zone (DRZ) will be created around the excavation. Compared to the host salt rock, the DRZ will exhibit increased porosity, increased permeability, and decreased load-bearing capacity. Over time, the DRZ extent, shape, and properties are expected to change as salt creep continues. Overall, the purpose of the proposed work is to provide a continuous picture of the formation, development and maturation of the DRZ around a newly excavated drift or panel.

A series of technical meetings was held between the SNL Carlsbad Programs Group (SNL/CPG), the Department of Energy/Carlsbad Field Office (DOE/CBFO), Washington TRU Solutions LLC (WTS), the WIPP Management and Operating Contractor (MOC), and other contractor personnel to discuss the existing data, the DRZ in the repository, the Air Intake Shaft (AIS) and possible avenues to improve the compliance baseline surrounding the DRZ. The following areas of interest emerged:

- Refine the extent of the DRZ.
- Quantify brine availability from the DRZ.
- Demonstrate healing around rigid inclusions.
- Evaluate geotechnical methods to measure and to monitor the DRZ.
- Assure EPA-monitored parameters are evaluated.

The activities described in this TP will help refine the current models that describe development of a DRZ, over time and space, in the host salt rock during and after excavation. Ultrasonic technology will be used to collect these data under this TP. These data will be complimentary to, rather than duplicating, data collected from previous and current DRZ tests. A brief description of previous and current DRZ ultrasonic velocity tests is provided below, followed by the objectives of the ultrasonic velocity tests governed by this TP.

3.1 Purpose And Scope Of The DRZ Characterization Mine-By Test

The utilization of ultrasonic technology to study the development of the DRZ in the WIPP Repository has a history that dates back to the early test programs in the WIPP repository. Ultrasonic transducers were considered, and used, to study the development of the DRZ during the mining of excavations in the repository. The Room G, wedge-shaped pillar (mine-by) test was to incorporate the use of ultrasonic transducers to monitor the early development of the DRZ during the mining of the pillar (Brekken and Van Sambeek, 1986). Unfortunately, the pillar test program was cancelled. However, an ultrasonic velocity mine-by test was successful in collecting early DRZ development data during the mining of Room A3 (Holcomb, 1988).

Ultrasonic velocity technology has also been used successfully in tests designed to study the development of the DRZ in excavations previously mined in the WIPP repository. In one of these tests, three ultrasonic velocity transducer arrays were emplaced in the AIS (Matalucci, 1987). These three arrays successfully provided data documenting the development of the DRZ around the AIS for approximately ten years (Holcomb, 1999; Hardy and Holcomb, 2000). To date, the three arrays continue to collect data.

A more recent application of ultrasonic velocity technology to study the development of the DRZ occurred in a drift (S-90 Drift) and alcove (Room Q Alcove) mined in the WIPP repository approximately twelve years earlier (Holcomb and Hardy, 2001; Holcomb et al., 2002). A pair of SNL-designed ultrasonic velocity tools (Figure 1), containing two transducer housings coupled together, performed cross-hole and same-hole measurements in borehole arrays located in the drift wall and the alcove inside corner. Figure 2 is a photograph of test operations near Room Q. The approach is similar to that used by Maxwell, et al., 1998. At both locations, the DRZ was observed to extend to shallower depths than previously observed. In the testing of the alcove inside corner, a complex pattern of damage was observed, corresponding to the complex stress state present around a corner in a material (salt) that exhibits both brittle and creep-related damage.

This TP outlines a program to refine the definition of the DRZ in the WIPP repository, building upon the successes of previous ultrasonic velocity tests. It is most likely that ultrasonic tests will be conducted in the waste disposal area of the repository because most future mining will occur there. The ultrasonic data collected under this TP will be complimentary to, rather than duplicating, data collected from previous and current DRZ ultrasonic velocity tests.

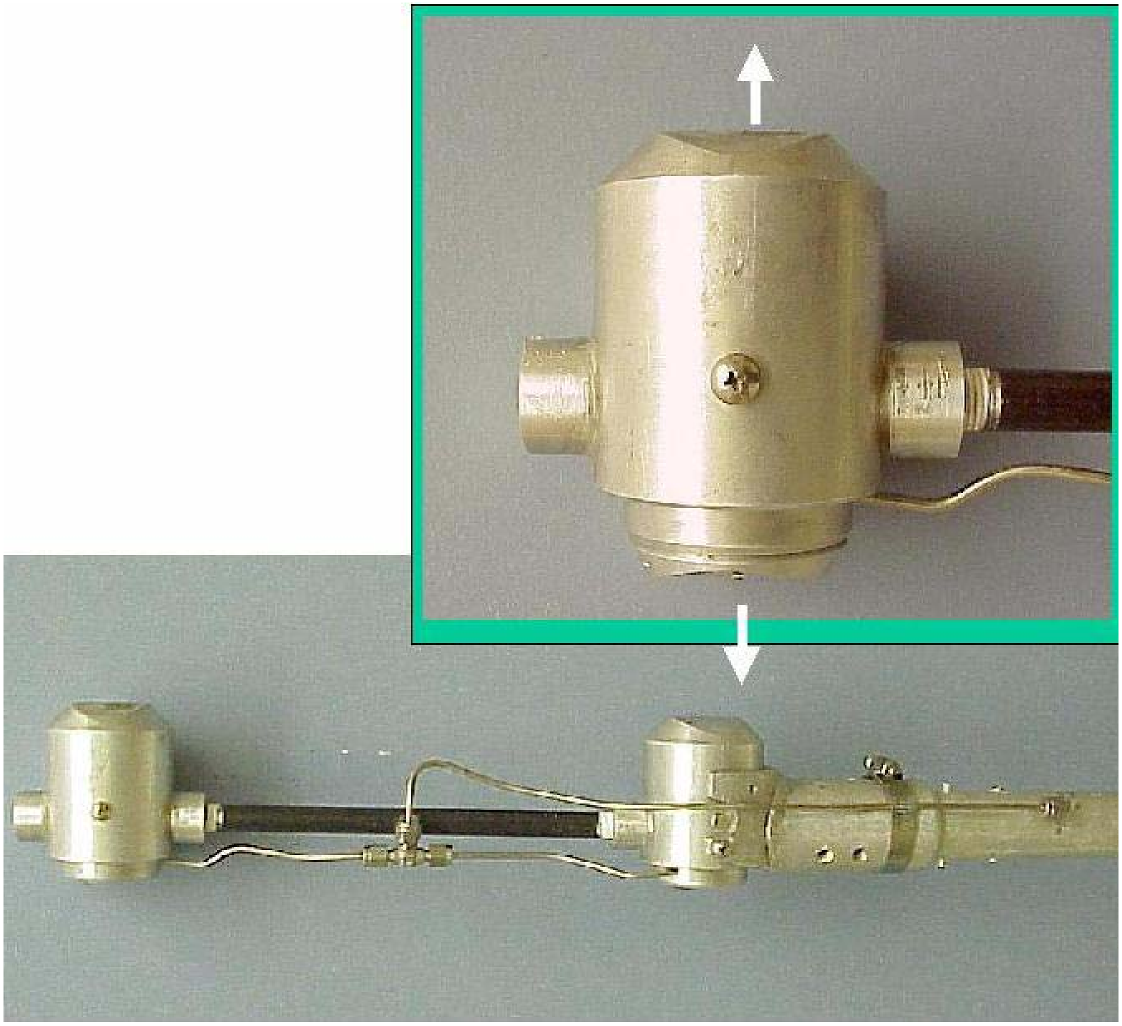

Figure 1. Transducer assembly showing two air-actuated clamping heads. Enlarged photograph is a close-up of one of the heads with the direction of motion during clamping indicated by arrows.

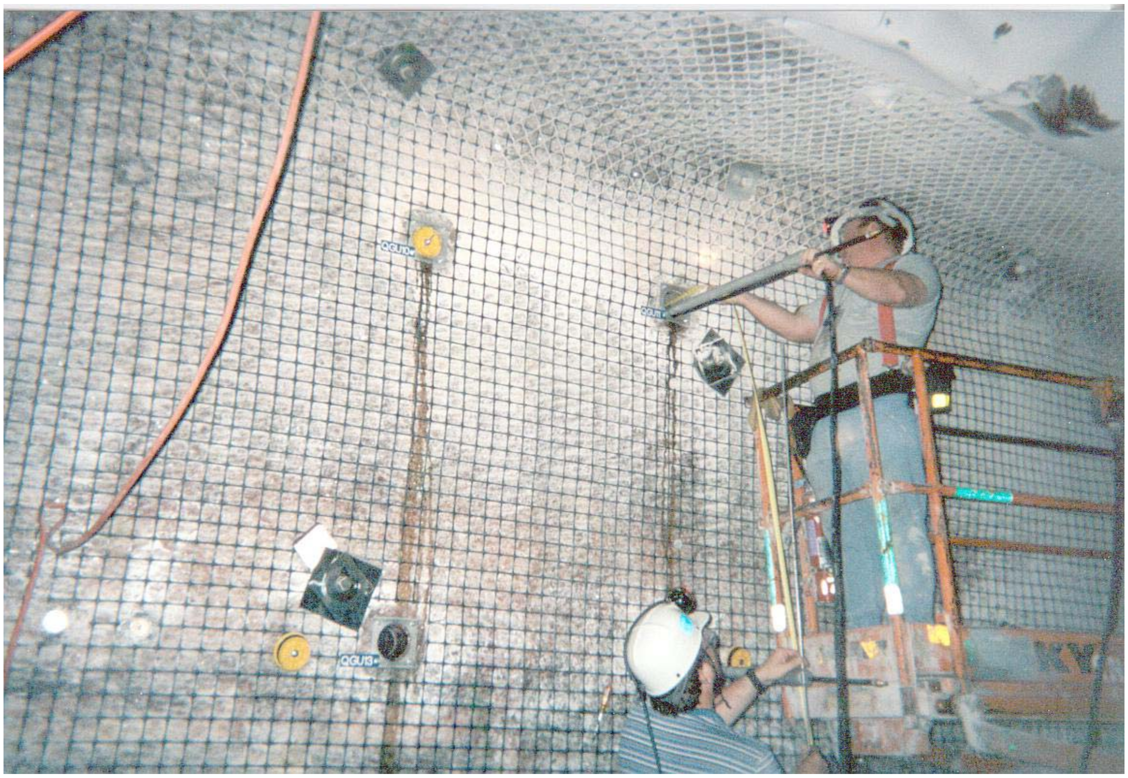

Figure 2. Example of hole array and insertion process for emplacing ultrasonic transducers.

4 EXPERIMENTAL PROCESS DESCRIPTION

This section of the TP describes the experimental processes required to study the development of the DRZ in the waste storage area (or equivalent newly mined area) of the WIPP repository during mining activities (hence this test is referred to as "mine-by"). The developing DRZ will be monitored using pairs of ultrasonic transducers (housings) emplaced in a borehole array drilled parallel to the proposed mine-by test site prior to the mining of the excavation. Velocity and acoustic emission (AE) data will be collected prior to the mining of the excavation, during mine-by, and into the foreseeable future. Development boreholes should be drilled prior to the commencement of mine-by test activities to develop drilling techniques, refine ultrasonic testing techniques, and determine a maximum possible drilling depth.

All measurements are based on the use of piezoelectric transducers to convert electrical impulses to mechanical motion for determining the elastic wave velocities and in the inverse mode, to convert mechanical motion due to grain scale failures (AE) into electrical signals. For velocity measurements, piezoelectric transducers (PZTs) are used as both the transmitter and receivers of the ultrasonic elastic waves. Only compressional mode transducers are used, although in certain configurations, a shear mode can be generated. A 300 kHz, PZT-5A piezoelectric disk is the basic element. Each disk is mounted inside a housing capable of being forced against the side of the 4-in boreholes using air pressure. Suitably curved faces on the aluminum housing increase the area of contact when the housing is extended by pressurization to, typically, 60 psi. To further, and very substantially, increase the energy transmission across the housing-rock interface, a couplant is extruded between the housing face and the rock. Corn syrup was used previously as the couplant; it is inexpensive, cleans up easily and provides good coupling for both compressional and shear elastic waves.

Two transducer housings are coupled together (Figure 1) to form the basic measurement tool inserted into the borehole. By placing two transducers in one hole, one transducer can be driven as a transmitter while the other acts as a receiver, similar to a technique discussed by Maxwell et al., 1998. In this way, same-hole measurements can be made along paths parallel to the future rib face and orthogonal to the inter-hole axes. As the orientation of the damage is expected to be anisotropic, additional information is gained by measuring the effects of damage along orthogonal paths. In particular, it is expected that the cracking planes will be preferentially parallel or sub-parallel to the rib, resulting in the largest changes in velocity along paths normal to the rib.

A small array of transducer pairs would be inserted into three holes drilled parallel to the future axis of a drift or panel prior to mining (see Figure 3). Nominally three pairs would provide coverage perpendicular and parallel to the future axis, and provide some redundancy against transducer failure after insertion. Locations of the transducers will be determined by the PI and depend upon the hole configuration and depths actually obtained.Figure 3 is a sketch of a possible layout for installation near a future drift. Actual hole spacing will depend on the accuracy that can be attained in hole placement and will be ascertained during the developmental borehole phase of the work. If excellent control of the hole position is found to be possible, then the position of the hole closest to the to-be-mined excavation will be adjusted closer to the drift wall. The risk is that accumulated errors will cause the hole to penetrate the to-be-mined salt, resulting in the loss of that part of the array. The advantage is that the DRZ develops faster, closer to the excavation.

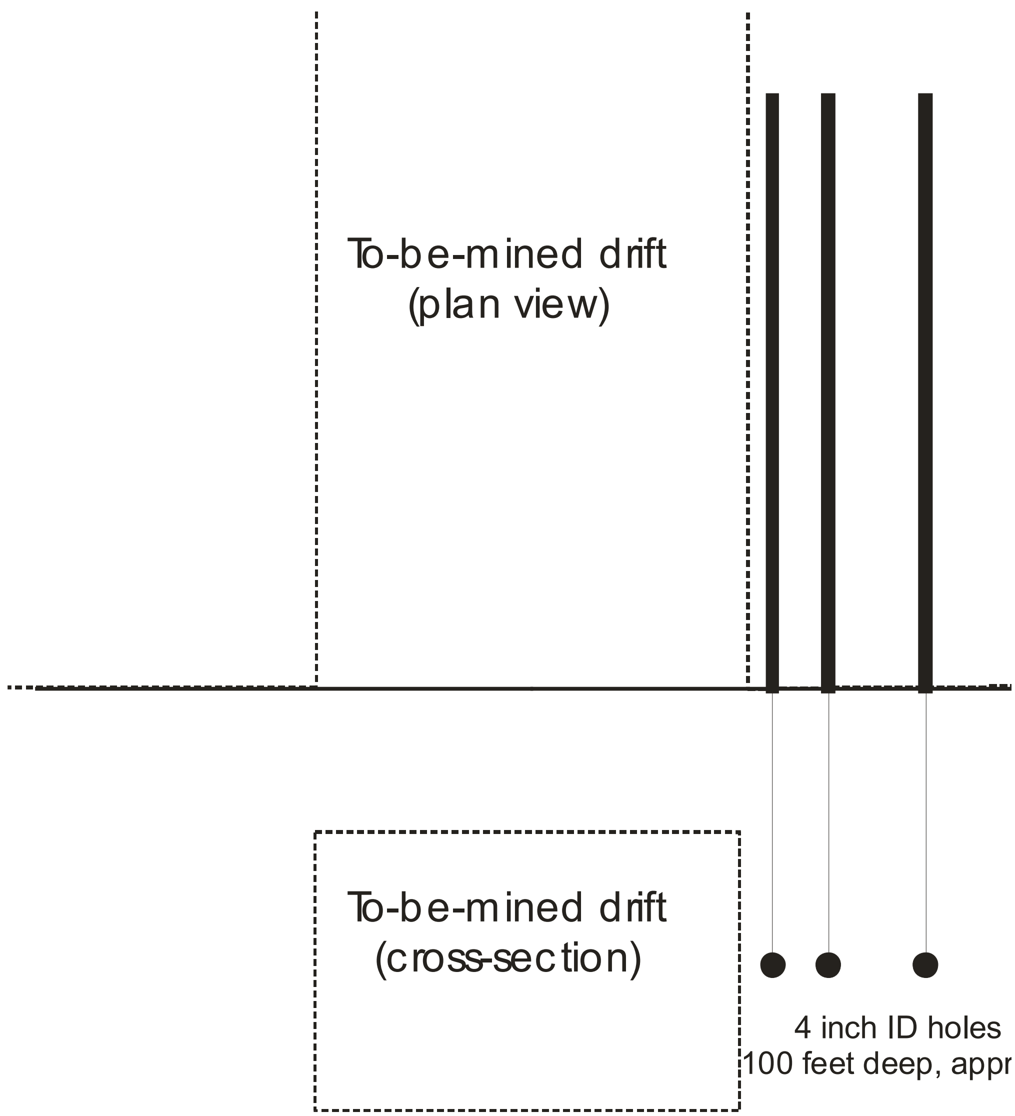

Figure 3. Sketch of hole layout for mine-by test when constructed in the rib of a future drift. Drawing is not to scale. Nominal rib-hole spacings would be 2, 4 and 10 feet.

For the velocity measurements, the transducers are driven by a pulse generator, controlled by a personal computer, and its associated instrumentation. The personal computer records the waveforms from the pulser and transducers for later analysis by the Principal Investigator (PI). The system will allow for unattended operation. These tests will allow the PI to evaluate the development of the DRZ into the host rock along the borehole walls. Sketches and documents associated with the design and construction of the ultrasonic test system will be submitted to the SNL/CPG Records Center (Records Center).

Key elements in obtaining quantitative data on the spatial development of the DRZ are precise placement of the boreholes and determining the position of the transducers to high accuracy, both relative to the excavation, and each other. Ideally, one of the boreholes can be placed within 300 to 600 mm of the drift wall, to allow observation of the DRZ in the early stages when it is expected to be developed only near the surface of excavation. This placement requires surveying in precise front and back drill-alignment prior to drilling the boreholes, followed by surveying the axis of the as-built holes to millimeter accuracy. It is the desire of this TP to have the WTS Mine Survey Crew (Survey Crew) perform the surveying activities.

Velocity measurements respond to the bulk properties of the salt. In particular, as the elastic moduli are degraded by grain-scale cracking, elastic wave velocities will decrease. It is of interest to know the degree to which brittle cracking is occurring at various phases of the development of the DRZ. Using the same piezoelectric transducers, the ultrasonic burst of sound emitted when a grain-scale crack forms rapidly (AE) can be detected, and if several of the transducers detect the same event, it can be located. Thus, two types of data can be garnered from the same installation: long-term bulk changes in properties from the velocity measurements and instantaneous determinations of the extent of brittle cracking and its location. The AE system uses essentially the same equipment as the velocity-measuring system.

All of the TP activities conducted in the WIPP repository will be coordinated through WTS, the WIPP MOC. TP activities will follow the WIPP Work Control Process (Work Control), which governs all activities conducted at the WIPP. All TP activities will be documented in a scientific notebook(s). No coring, core recovery, or core analysis is proposed for this TP. If a decision is made at a future date to obtain core, a revision or addendum to this TP will be prepared.

4.1 Development Boreholes

Boreholes of the type specified for the TP have not been drilled in the WIPP repository in a number of years. Specifically, an array of three (or more) horizontal, 4-in inside diameter (ID) boreholes will need to be drilled in the host salt (halite) rock, parallel to the candidate location, prior to the mining of the excavation. These boreholes will be drilled to a depth of 100 ft, or as deep as possible and still maintain line-of-sight with the back of the borehole. These boreholes will also be drilled as parallel as possible. The extraction of salt core samples (if requested) from these depths has not been attempted in a number of years. This TP does not include core retention for any technical or QA purpose. Special tools may have to be developed to extract core samples from the deeper borehole depths. Previous experience has shown that a smooth borehole surface is desired.

It is assumed that the WTS Mine Drill Crew (Drill Crew) will drill the boreholes associated with this TP. The Drill Crew will require experience with the drilling equipment and techniques to drill the precision boreholes for placement of the ultrasonic transducers. If the Drill Crew is unable to drill the deep precision boreholes required by this TP, alternate sources will be considered to drill the boreholes (i.e., outside drilling contractor). The same level of experience is required with the core-capture equipment. This experience can only be obtained by drilling development boreholes in WIPP repository salt (halite) rock similar to the candidate mine-by test.

Several candidate locations for drilling two (or more) development boreholes exist in the WIPP repository. One possible location is DRZ Test Location 2 (Location 2), located in the S-90 Drift. Location 2 is near the DRZ ultrasonic velocity test sites at S-90 Drift and Room Q Alcove. Similar beds of salt (halite) rock exist at Location 2 (Mapping Unit 3) and in the waste storage area (Mapping Unit 6) of the WIPP repository. Drilling the development boreholes at Location 2, prior to drilling the boreholes at the candidate mine-by test site, will provide requisite experience before the mine-by holes are drilled. It is noted that the southern section of the repository is raised 2.43 meters upward from the S-90 location, and the salt horizon for the actual test holes will be elevated similarly. However, the S-90 location is out of the way of underground operations and allows the techniques for drilling long holes to be developed without interfering with waste receipt.

The Drill Crew will drill the 4-in ID, horizontal development boreholes with an air-powered rock drill supported on an H-frame. The SNL Mine-By PI, or his designee, will determine the number and location of the drilled boreholes. It is proposed that a 4-in outside diameter (OD), diamond and surface-set, solid face bit (or equivalent) will be used to drill the boreholes. Owing to the extreme length of drillhole, core acquisition is not proposed for this TP.

Surveying the development boreholes will provide the Survey Crew an opportunity to determine if they can precisely quantify X, Y, Z coordinates over the entire length of a 100-ft borehole. If the Survey Crew is unable to survey the borehole coordinates to the precision required by this TP, alternate sources will be considered to perform these measurements (i.e., special borehole survey equipment).

Cross-hole and/or same-hole ultrasonic velocity tests will be performed in the development boreholes. The data gathered from these tests will assist the PI in configuring the permanently mounted transducers emplaced in the mine-by test boreholes. Tests conducted in the development boreholes with the ultrasonic velocity tools will be governed by SNL NWMP Activity/Project Specific Procedure (SP) 9-3 (see Subsection 9.4).

The sequence of activities associated with drilling development boreholes is as follows:

1. The PI (or designee) will determine the specific number and location of the development boreholes. The PI will determine the intervals to be cored.
2. The PI will complete all required Work Control documentation and submit the package to cognizant WTS personnel for review and approval. The package should contain a copy of the TP and should encompass all activities associated with the TP.
3. Upon approval of the Work Control package, the PI will schedule the layout of the front and back drill-alignment boresites for the development boreholes at Location 2 (or alternate site) with the Survey Crew.
4. The PI will schedule the assembly of the drill and H-frame at the selected development borehole location. The PI and/or Drill Crew supervisor will approve the final setup for each development borehole.
5. The Drill Crew will drill each development borehole to a depth of 100 ft, or until line-of-sight with the bottom of the borehole is 50% lost, as determined by the PI. Line-of-sight with the bottom of the borehole will be verified at a minimum of every 20 ft using a downhole reflector and uphole light source (or equivalent). An outside coring contractor or alternate drilling equipment may drill the development boreholes if the Drill Crew is unable to attain the precision required by this TP.
6. The drill and H-frame will be removed from Location 2 (or alternate site) upon the completion of the drilling of the development boreholes.
7. Alignment plates will be mounted to the rib collar of each development borehole to facilitate borehole surveying and ultrasonic velocity testing (if performed). Each rib collar location may have to be ground smooth to accommodate an alignment plate.
8. Each development borehole will be cleaned out (i.e., brushed and air-blown) in preparation for borehole coordinate measurements and ultrasonic velocity testing.
9. The Survey Crew will establish periodic X, Y, Z coordinates at defined locations or regular intervals in the completed boreholes. Special borehole survey equipment may be used if the Survey Crew is unable to survey the borehole X, Y, Z coordinates measurements to the precision required by this TP.

10. SNL/CPG personnel will record periodic ID measurements in the completed boreholes. The diameter measurements should be made as close as possible to the X, Y, Z coordinates established in Step 9.
11. The PI will determine if cross-hole and/or same-hole ultrasonic velocity test measurements are performed in the development boreholes. The PI will determine the distance between the test measurement locations. Ultrasonic velocity tests conducted in the development boreholes are governed by SP 9-3 (see Subsection 9.4). The ultrasonic velocity tests will be documented in a scientific notebook(s).
12. The development boreholes will be plugged with sewer plugs (or equivalent), to retard brine crystallization and limit dirt infiltration, except during observational studies and/or future testing.
13. The Team Leader will prepare a supplemental report summarizing cross-hole and/or same-hole ultrasonic velocity test results obtained from the observational boreholes.

4.2 Mine-By Test

The main objective of this TP is the emplacement of the ultrasonic mine-by test array to study the development of the DRZ during and after the mining of an excavation in the WIPP repository. This TP recommends the emplacement of the array in a location of the waste disposal area where it will not interfere with the mining. The WTS Mine Operations Department (Mine Ops) will be consulted regarding placement of the array near a future drift. The location and actual drilling of the array boreholes will depend upon the completion of the development boreholes test activities, and the mining schedule of the waste storage panels. The PI may change the layout and number of array boreholes (i.e., a delta or L pattern), prior to commencement of drilling activities, to ensure the most appropriate monitoring of the development of the DRZ. Changes to the mine-by test array will be documented in a scientific notebook.

The requirements for the drilling of the mine-by test array boreholes parallel those of the development boreholes (Subsection 4.1). The depth to which the array boreholes will be drilled (100 ft desired) will depend upon the accuracy of the drilling of the development boreholes. The driller of the array boreholes will depend upon the success of the Drill Crew at drilling the development boreholes. The coordinate measurement technique used in the array boreholes will be determined by the results of surveying the development boreholes. The development borehole ID measurement technique will also be used in the array boreholes. As with the development boreholes, a diamond surface-set, solid face bit (or equivalent) will be used to drill the array boreholes, except in the emplacement intervals, where coring will be done to obtain an acceptable surface finish. In those intervals, the array boreholes will be drilled with a diamond surface-set core barrel (or equivalent).

A procedure does not currently exist to govern the installation and operation of the ultrasonic test system. The installation and "shakedown" of the transducer housings, Data Acquisition System (DAS) or personal computer, and associated instrumentation will be documented in a scientific notebook(s). A new SP will be written, or the current version of SP 9-3 (see Subsection 9.4) modified, to govern the day-to-day operation of the ultrasonic system. Sketches and documents associated with the design and construction of the ultrasonic mine-by test system will be submitted to the Records Center.

The sequence of activities associated with the emplacement mine-by test array will be essentially the same as used for development holes:

1. The PI (or designee) will determine the specific number layout, and location of the mine-by test array boreholes. The PI will determine if salt core samples are to be recovered so that the appropriate drilling bit/barrel can be selected.
2. The PI should have completed and submitted the required Work Control documentation for all activities associated with the TP (Subsection 4.1).
3. The PI will schedule the layout of the front and back drill-alignment boresites for the array boreholes at the selected mine-by test location with the Survey Crew.
4. The PI will schedule the assembly of the drill and H-frame at the selected mine-by test location. The PI and/or Drill Crew supervisor will approve the final setup for each mine-by borehole.
5. The Drill Crew will drill each array borehole to a minimum depth of 100 ft, or until line-of-sight with the bottom of the borehole is 50% lost, as determined by the PI. The drilling of the development boreholes should provide an indication as to how deep 4-in ID boreholes can be drilled in the WIPP repository and maintain line-of-sight to the bottom of the borehole. Line-of-sight with the bottom of the borehole will be verified at a minimum of every 20 ft using a downhole reflector and uphole light source (or equivalent). The driller of the array boreholes will be selected based upon the drilling results of the development boreholes.
6. The drill and H-frame will be removed from the mine-by test array location upon the completion of the drilling of the mine-by boreholes.
7. Alignment plates will be mounted to the rib collar of each array borehole to facilitate borehole surveying and the emplacement of the ultrasonic transducers. Each rib collar location may have to be ground smooth to accommodate an alignment plate.
8. Each array borehole will be cleaned out (i.e., brushed and air-blown) in preparation for borehole coordinate measurements and installation of the ultrasonic transducers.
9. The Survey Crew will establish X, Y, Z coordinates at defined locations or regular intervals along the completed array boreholes. The PI will determine the distance between coordinate measurements. The coordinate measurement technique used in the array boreholes will depend upon the results of the surveying of the development boreholes.

10. SNL/CPG personnel will record periodic ID measurements in the completed array boreholes. The diameter measurements should be made as close as possible to the depths where X, Y, Z coordinates measurements were determined in Step 9.
11. Pairs of ultrasonic transducers (housing) will be emplaced at their designated coordinates in their designated array borehole as determined by the PI. The installation of the transducers will be documented in a scientific notebook(s).
12. The ultrasonic transducers will be connected to the DAS/personal computer and a shakedown performed on the entire ultrasonic test system. The evaluation will be documented in the scientific notebook(s).
13. The ultrasonic test system will be configured for long-term DRZ development monitoring. Cognizant personnel will periodically download data from the DAS for analysis by the PI.
14. An SP will be written, or modified, to govern the day-to-day operation of the ultrasonic mine-by test system.
15. The array boreholes will be plugged with sewer plugs (or equivalent), to retard brine crystallization and limit dirt infiltration, except during observational studies, additional testing, and/or ultrasonic transducer maintenance.
16. Upon the completion of all TP activities, the PI will finalize the Work Control package and submit the original package to Work Control and two copies to the Records Center.
17. The PI will prepare a report summarizing the installation and operation of the ultrasonic mine-by test system. The PI will also prepare periodic supplemental reports updating the development of the DRZ at the test location.

4.3 Modifications To Experimental Process

Modifications to test procedures outlined in TP Section 4 may be required during test deployment. These modifications will be conducted at the direction of the PI, and will be documented in the scientific notebook(s) as part of the QA records. Such modifications are not deviations and will not be reported as non-conformances that require corrective action.

If test conditions deviate appreciably from the anticipated execution of the current version of this TP, the TP will be revised.

5 DRILLING AND TEST EQUIPMENT

This TP will require equipment to drill deep, precision boreholes to survey the location and X, Y, Z coordinates of each borehole and the ultrasonic transducers and to monitor the development of the DRZ (i.e., a DAS). The equipment may consist of “off the shelf” items ordered directly from qualified suppliers, standard equipment provided by qualified service companies, and/or custom-built equipment designed and built for a specific task(s) governed by the TP. All equipment used will follow the supplier’s/designer’s operation and calibration recommendations (as required). All equipment with calibration requirements and quality-affecting operations will be documented as part of the QA records and controlled by NP 12-1 (see Subsection 9.4).

5.1 Drilling Equipment

The Drill Crew (preferable) or a drilling contractor will drill the boreholes required by this TP. Equipment will be operated observing relevant manufacturer and WIPP Environment, Safety and Health (ES&H) procedures and protocols.

5.1.1 Drill

The Drill Crew or drilling contractor will select the drill and support frame used to drill the boreholes required by this TP. Mine Ops recommends utilizing a Longyear Model D-65 air-powered drill (or equivalent) mounted on an H-frame to drill the boreholes. Mine Ops also recommends using air as the cutting fluid for drilling the boreholes to preserve their mechanical properties. The use of air is mandatory. The Drill Crew or drilling contractor is responsible for providing all equipment necessary to meet the drilling requirements of this TP.

5.1.2 Drill Bit/Core Barrel

The PI will determine the depth intervals where salt core samples, if any are extracted from the boreholes. Mine Ops recommends using a 4-in OD, diamond surface-set, solid-face bit (or equivalent) to drill boreholes. At the time of this writing, no core recovery is planned for these holes. The use of air is mandatory. Air drilling has been successfully used in previous operations of this nature. SNL/CPG will purchase the solid face bits and/or core barrels required to drill the boreholes, based upon recommendations by Mine Ops and/or the drilling contractor.

5.1.3 Utilities and Support

WTS Underground Services (U/G Services) will provide the plant electrical and compressed-air drops necessary to support the activities outlined in this TP, in particular the drilling of the boreholes. U/G Services will also provide equipment (i.e., forklifts, scissor-lifts) and operators, as required, to support this TP. These requirements will be specified in the Work Control Package.

5.2 Surveying Equipment

The Survey Crew will use a survey total station (or equivalent) to survey the front and back drill-alignment boresites for each borehole drilled to support this TP. The Survey Crew will also attempt to survey X, Y, Z coordinates with the survey total station by measuring the position of a reflective target placed at periodic distances in the borehole. Special borehole survey equipment may be used if the Survey Crew is unable to survey the X, Y, Z coordinates to the bottom of the boreholes. SNL/CPG personnel will make periodic ID measurements at each X, Y, Z coordinate location along the borehole using a borehole caliper.

5.2.1 Survey Total Station

The Survey Crew will use a Leica Model TC1800 survey total station (or equivalent) to survey the front and back drill-alignment boresites of each borehole drilled to support this TP, using a known WIPP repository survey point near the test locations for reference. The Survey Crew will attempt to survey periodic borehole X, Y, Z coordinates with the Leica survey total station used in conjunction with a SNL-designed and built, self-centering, reflective target. The reflective target is placed at periodic locationsalong each borehole and surveyed with the Leica survey total station. Special borehole survey equipment may be used to measure the boreholes X, Y, Z coordinates if measurements with theLeica survey total station prove unsuccessful. Measurement data are combined with their corresponding diametric measurement data to assist the PI in accurately placing the SNL-designed ultrasonic tools in the development and mine-by test array boreholes, and accurately quantifying the absolute ultrasonic velocities.

5.2.2 Borehole Caliper

SNL/CPG will use an SNL-designed and built, borehole caliper to take periodic measurements of the ID of each borehole drilled to support this TP. The diameter measurements for each borehole should be madeas close as possible to the X, Y, Z, coordinates measurements made in that borehole. These measurements are used to place ultrasonic tools in the boreholes and to correct the time delay of the ultrasonic velocity signals captured by the ultrasonic transducers.

5.3 Down-Hole Ultrasonic Test Systems

Two assemblies, each containing two ultrasonic transducer housings coupled together, may be inserted into a pair of developmental boreholes at periodic distances to measure the host salt rock DRZ. In the mine-by test, similar pairs of ultrasonic transducer housings will be permanently emplaced in each array borehole. In both test systems, the DAS or personal computer and its associated instrumentation trigger the transducers to emit an ultrasonic pulse, and condition and store the return signal from the transducers for analysis by the PI when determining elastic wave velocities. In the passive mode, the output of the array of transducers will be recorded, after suitable conditioning, to enable the detection and location of AE. Given the proximity to active mining operations and the long duration of the experiment, it will be necessary to have a fixed installation for the electronics and a small work area.

5.3.1 Ultrasonic Test Assembly

An SNL-designed and built ultrasonic (acoustic) test assembly will be used to take periodic measurements of the DRZ in the Location 2 developmental boreholes. Either the reconfigured test assembly used to measure the DRZ in the Q Alcove (Holcomb et al., 2002), or a new test assembly, will be utilized to measure the DRZ in the mine-by array boreholes. The test assembly typically consists of two ultrasonic transducer housings coupled together and attached to the end of a set of push rods to be inserted at various, known distances down the borehole. Each housing will contain a compressional-mode ultrasonic transducer. The housings contain pressure-activated pistons that seat the transducers against the borehole wall. A coupling agent (i.e., Karo™ syrup) is pumped through the pistons to improve contact with the borehole wall. A DAS or personal computer is used to control the ultrasonic velocity test equipment and to acquire and store data. A pulse generator is used to excite one transducer to emit an ultrasonic pulse into the host salt rock. An identical second transducer detects the transmitted signal and the signal is passed onto an amplifier. The return signal will be displayed on an oscilloscope for real-time review by the PI. Acceptable return signals (data) are stored by the DAS or personal computer for future analysis by the PI. A manual or electronic A-B switch may be used to switch between two transducers located in each housing. The pulse generator, amplifier, and A-B switch may be consolidated into the DAS or personal computer. Sketches and documents associated with the configuration of the ultrasonic test assembly and test equipment will be submitted to the Records Center.

5.3.2 Permanent-Emplaced Ultrasonic Transducers

Pairs of SNL-designed-and-built ultrasonic (acoustic) transducer housings will be permanently emplaced in each of the mine-by test array boreholes. Locations will be determined by the PI and depend on the condition and depths of holes. The construction of the mine-by test housings will be similar to the construction of the ultrasonic velocity test assembly housings. Each housing will be permanently emplaced in each borehole by mechanical (i.e., spring-loaded), hydraulic, or electrically-activated pistons, as determined by the PI. A coupling agent may be used to improve coupling to the borehole wall. A DAS or personal computer is used to control the ultrasonic test equipment and to acquire and store data. The DAS or personal computer will periodically activate a pulse generator to excite the transducers to emit a pulse. A second transducer captures the transmitted signal, which is then passed onto an amplifier. The signal (data) is stored by the DAS or personal computer for future analysis by the PI. The DAS or personal computer controls an electronic switch controller, which allows switching between housings in an array borehole and/or transducers in a housing. The pulse generator, amplifier, and switch controller may be consolidated into the DAS or personal computer. The data collected from the transducers may ultimately migrate to the WIPP repository DAS for data archiving. Sketches and documents associated with the configuration of the ultrasonic transducer housings and test equipment will be submitted to the Records Center for data archiving. Sketches and documents associated with the configuration of the DAS or personal computer will also be submitted to the Records Center.

5.3.3 WIPP Repository DAS

The resident WIPP repository DAS, currently a Campbell Scientific DAS, is receiving and archiving AIS and Room D instrumentation data. If compatibility issues can be resolved, mine-by test ultrasonic data may migrate to the WIPP repository DAS for long-term archiving. The WIPP repository DAS will facilitate ease of access to mine-by test data. Sketches and documents associated with the migration of the DAS or personal computer data to the WIPP repository DAS will be submitted to the Records Center.

6 DATA-ACQUISITION PLAN

Both manually- and electronically-collected data will be acquired during the developmental and mine-by test activities. The following types of data may be recorded:

- electronically-collected ultrasonic data from the DAS or personal computer,
- electronically-collected borehole and transducer housing survey data from WTS Survey Crew equipment, and
- manually-collected core data.

6.1 Scientific Notebook(s)

A scientific notebook(s) will be used in accordance with NP 20-2 (see Subsection 9.4) to document all SNL/CPG activities and decisions during the TP. Specific information that may be entered in the scientific notebook(s) consists of:

- a statement of the objectives and description of work to be performed, as well as a reference to this TP;
- a written account of all activities associated with the development and implementation of the mine-by test;
- documentation of safety meetings;
- a list of equipment used during each activity, including make, model, and operating system (if applicable);
- traceable references to calibration information for instruments and/or gauges calibrated elsewhere; and
- discussions of the information and/or observations leading to decisions to initiate, terminate, or modify test activities.

All entries in the scientific notebook(s) will be signed and dated by the person making the entry. The scientific notebook(s) for this TP will be reviewed by an independent, technically-qualified individual within 30 days of the end of the activities governed by this TP to verify that sufficient detail has been recorded to retrace the activities and confirm the results.

Manually-collected data may also be recorded on specially-prepared forms rather than in the scientific notebook(s) when that process will provide a more efficient means of data collection and tracking. Use of such forms will be noted in the scientific notebook(s) and these forms will be technically reviewed and submitted as QA records.

6.2 Electronic Data Acquisition

The DAS will be used to record instrumentation data during the test. Additional electronic data may be acquired from the WTS Survey crew. Electronic data file-management information will be documented in the scientific notebook(s) for these activities. These electronic data files will be submitted as QA records according to NP 17-1 (see Subsection 9.4)

6.3 Manual Data Acquisition

Manual data collection will be carried out during the test using a scientific notebook(s) or forms designed specifically for each activity or data type. Information will be documented such that duplication of information will be minimized. The PI will determine the means of documenting manually-acquired data and will ensure that all quality-affecting information is documented.

6.4 On-Site Validation

During the test activities, the PI will evaluate the data, as they are acquired. The data will be diagnosed for any equipment failure and/or procedure-induced effect that may degrade the data quality. The PI will take immediate action (if required) to make any necessary changes to the equipment configuration or the procedures to assure the data quality is consistent with the objectives of these activities.

The PI will use real-time evaluation of the acquired data during test activity to assure that the data are usable in a detailed interpretation, the conditions can be maintained over the planned duration of the activity, and an activity will not be terminated before the minimum objectives can be achieved under the given time restraints. The PI may utilize some or all of the following procedures and analytical tools:

- real-time inspection of signal quality to assure useable waveforms for velocity determination;

- real-time analysis of the acquired data to assess transducer positioning and proper operation of the DAS; and

- real-time analysis to determine whether or not an activity can be terminated earlier than planned, with concurrence from cognizant WTS personnel, and to develop a revised schedule as appropriate.

If at any time the PI determines that a test activity objective cannot be accomplished due to time constraints, problems concerning the performance of the equipment, or unsuitability of initial conditions, the PI will consult with cognizant WTS personnel to terminate the activity, or develop a recovery plan. The PI will document all real-time evaluation of data and conditions in the scientific notebook(s).

7 SAMPLING AND SAMPLE CONTROL

The PI, prior to commencement of drilling a borehole, will determine the number, depth, and location of the core samples to be extracted. If the core samples are collected for laboratory analyses, they will be collected and controlled in accordance with NP 13-1 (see Subsection 9.4). The extracted core samples will immediately be logged and preserved in accordance with SP 13-2 (see Subsection 9.4). The chain of custody for the core samples will be established in accordance with SP 13-1 (see Subsection 9.4). It is not the intent of this TP to provide cores for analytical purposes. The PI can implement NP 13-1 (see Subsection 9.4) as conditions dictate. Otherwise the core will be considered non-quality assurance (NQ).

8 TRAINING

All personnel who will perform quality-affecting activities under this TP will have training in the SNL QA program (documented using Form NP 2-1-1) and have received Annual SNL QA Refresher Training, or have reviewed the latest revision of the SNL QA Refresher Video. These personnel will read NPs 12-1, 13-1, 17-1, and 20-2, and SPs 13-1 and 13-2 (see Subsection 9.4). At least one member of the test team will be qualified as an experienced underground miner as required by the WIPP MOC. No other special training requirements are anticipated in addition to that listed above and the safety briefings section of the TP.

9 QUALITY ASSURANCE

9.1 Hierarchy Of Documents

Several types of documents are used to control work performed under this TP. If inconsistencies or conflicts exist among the requirements specified in this document, the following hierarchy will apply:

- memoranda or other written instructions from the WTS Projector Leader or PI to modify or clarify the requirements of the TP (most recent instructions having precedence over previous instructions);
- this TP;
- SNL NPs;
- SNL SPs;
- manufacturer's procedures (i.e., calibration); and
- SNL QA concurrence and/or corrective action reports for modifications to QA procedures implemented for work conducted under this TP.

9.2 Quality-Affecting Activities

Activities performed under this TP are quality affecting with the following exceptions:

- operation of drilling equipment;
- assistance provided by WTS and/or contractors in the installation of equipment;
- support services for tasks that do not involve data collection, such as electrical power, compressed air, etc.; and
- waste disposal.

9.3 Quality Assurance Program Description

SNL/CPG activities are conducted in accordance with the requirements specified in the DOE/CBFO Quality Assurance Program Document (QAPD), CAO-94-1012, Revision 4. The requirements of the DOE/CBFO QAPD, and any revisions thereto, are passed down and implemented through the SNL NWMP QA Procedures.

9.4 QA Procedures

The NPs and SPs that may apply to work performed under this TP include:

- NP 12-1, "Control of Measuring and Test Equipment;"
- NP 13-1, "Control of Samples and Chemical Standards;"
- NP 13-2, "Logging and Management of WIPP Core Samples;"
- NP 17-1, "Records;"
- NP 20-1, "Test Plans;"
- NP 20-2, "Scientific Notebooks;"
- SP 9-3, "DRZ Acoustic Propagation Test System Operations;"
- SP 13-1, "Chain of Custody;" and
- SP 13-2, "Core Sample Logging and Management."

Modification to these procedures may be required during field activities. Such modifications are not deviations and will not be reported as non-conformances that require corrective action. However, the PI will document modifications to the SPs in the scientific notebook(s) as they occur as part of the QA records.

9.5 Manufacturers QA Procedures

Manufacturers' QA procedures that may apply to work performed under this TP includes:

None.

9.6 Data Integrity

Care will be taken throughout the performance of the operations for this TP to ensure the integrity of all data collected including documentation on hard copy and data collected on storage media. Duplicate copies of all data will be produced as quickly as possible and the duplicate copies will be maintained at a location separate from the test site to ensure that data are not lost.

9.7 Records

Records will be maintained as described in this TP and applicable QA implementing procedures. These records may consist of bound scientific notebook(s), loose-leaf pages, forms, printouts, or information stored on storage media. The PI will ensure that the required records are maintained and are submitted to the Records Center according to NP 17-1 (see Subsection 9.4).

9.7.1 Required QA Records

As a minimum, QA records will include:

- Scientific notebook(s);
- SPs used;
- Calibration records for all controlled equipment;
- Equipment-specification sheets or information (if available);
- Data files collected by the DAS, with a log listing the files and defining their contents;
- All forms containing manually-collected data;
- Core logs of all core samples (if extracted); and
- Reports provided by SNL/CPG Laboratory facility personnel.

9.7.2 Miscellaneous Non-QA Records

Additional records that are useful in documenting the history of the activities, but are considered non-QA records, may be maintained and submitted to the Records Center. These records include:

- safety briefings;
- ES&H documentation;
- as-built diagrams of equipment supplied by contractors;

- as-built diagrams of equipment supplied by vendors;
- equipment manuals and specifications;
- equipment manifests; and
- cost and billing information regarding contracted services.

These records do not support performance assessment (PA) or regulatory compliance and, therefore, are not quality-affecting information.

9.7.3 Submittal of Records

Records resulting from work conducted under this TP, including forms and data stored on storage media, may be submitted to the SNL/CPG QA Dept. for review and approval in individual pieces. Where possible, the records will be assembled into a records package(s), which will be reviewed by the PI before being submitted for QA review.

10 HEALTH AND SAFETY

The safety practices and polices will meet the requirements of the SNL ES&H Manual. Operational safety for individual SNL/CPG field operations will be addressed through a Safety and Health Hazards Control Document (SHHCD), an ES&H Primary Hazard Screening (PHS), a Hazard Analysis (HA), and a Pressure Safety Data Package (if required) developed by SNL.

The PI may conduct daily safety briefings at the beginning of daily operations. All daily safety briefings will be documented in the scientific notebook(s) and will include the name of the participants. The work location will maintain a mobile communication system (i.e., cellular telephone). In case of an accident, injury, or sudden illness, local emergency services will be contacted (as required) and the SNL/CPG Facility Manager will be notified.

11 PERMITTING/LICENSING

There are no special licenses or permitting requirements for the work described in this TP.

12 REFERENCES

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